Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 83 (2016) 902 – 906

Procedia Computer Science

The 6th International Conference on Sustainable Energy Information Technology (SEIT 2016)

# Application of dc-grid for efficient use of solar PV system in Smart Grid

"S.Rauf, A.Wahab, M.Rizwan, S.Rasool, N.Khan" *

*"Department of Electrical Engineering, COMSATS Institute of Information Technology, Park Road, Islamabad, Pakistan"*

**Abstract**

This paper is about efficient use of smart dc grid technology for photovoltaic distributed generation and utilizing it in smart way, to build infrastructure more reliable and to achieve the goal to cater the need for tomorrow. As there are many conversion losses from ac to dc, world is moving towards dc appliances as most of the electronic appliances at home accept dc power supply. Receiving dc power from Photovoltaic solar, it is clear there would be benefits in avoiding the conversion losses, especially when most of the devices used at home run on dc. This benefit is further enhanced if dc is directly used for lighting, electric vehicle charging, Digital equipment etc. PV solar energy produces dc power and if used directly then power loss will be minimized. Exact calculation of solar panels and proper battery sizing leads to a reliable distributed generation system. 240Vdc grid will also help to minimize the power transmission losses for up rise buildings, this will further enhance the system efficiency. Proper selection of wire minimizes the electric corrosion. Series and parallel combination of PV and battery cells will enhance the use of suitable power supply for each electronic device. Other side where ac supply is required 240Vdc directly converts to 240Vac for Ac machines such as conventional appliances in order to minimize transformer losses. This paper also presents an idea for smart load shedding techniques and its practical implementation in the form of smart dc Grid. Its various applications will enhance the functionality of a smart Dc grid on residential load.



*Keywords:* "Distributed Generation; Smart Grid; Electric Vehicles; dc Load; dc Grid; Photovoltaic"

## 1. Introduction

In past few years a lot of research work has been done on smart grids. The main goal of this paper is to develop more reliable and robust system for catering the power demand. Along research within smart grids, the current

* Corresponding author. Tel.: +92-321-592-0070 ; fax: +92-53-364-3034
*E-mail address:* shoaibrauf@hotmail.com


doi:10.1016/j.procs.2016.04.182

power network involves the implementation of distributed generation sources [1]. Roof top homes have become more popular for PV solar systems. These PV systems are further connected to the local grid using many inverters and can produce many harmful impacts such as harmonics in the national grid. There is remarkable power loss due to conversion from dc solar PV to ac power at traditional grid and then back to dc for our digital devices and dc loads. Preferable source of power for most of appliances is dc due to the increasing research in electronics [2].

Inefficient rectifiers and power supplies are used, which add harmful impact on over all power system.Many devices like LED lights, Televisions, mobile chargers, personal computers, audio systems use dc supply. In this paper an alternate smart grid is designed and it is suggested to minimize the variable power conversions.A smart control priority is also defined for the system which provides extra benefit during peak hours and maximum utilization of solar PV at day time and smart battery storage during night with prediction of weather conditions and load forecasting [3].

Another view point is discussed in this paper, user accessibility to control load and operation of grid. With the integration of solar PV, end users are participating in the operation of that system. It is significant to give then a little bit ability to control their usage and have some influence over the grid as well.
Here a residential home has solar photovoltaic array on roof top, Plug in Electric Vehicle (PiEV) on road [4], the efficiency of the whole system is much higher if the PV power is not converted to ac. In between is battery storage cells which allows compatibility for different dc appliances just like Toys with different series and parallel combination of cells but here with more amperes hour ratting, many combinations to produce variable dc voltage levels than going dc-ac-ac conversion. These conversion losses alone slaps on the overall efficiency of the system.

## 2. System Desigh

This smart grid consist of interconnected individual PV solar panels and batteries connected in series and parallel configuration according to the desired demand of the load. “n” number of batteries of each “x” Vdc are connected in series parallel configuration which will be charged by “n” number of PV solar panels of each “y” Vdc. Laptops, mobile chargers, LED lights, dc fans, internet routers, dc submersible water pumps, dc motor compressors for refrigeration and air conditioning for cold storage plants are very much used commonly nowadays. Since each of device is operated at its own specified dc voltage, series and parallel combination of each battery cell can help to maintain specified level of voltage. Commutative property of dc help to add each cell of dc to get desired level of dc, as there is much difficulty of adding two ac sources because of synchronization required for frequency in ac.

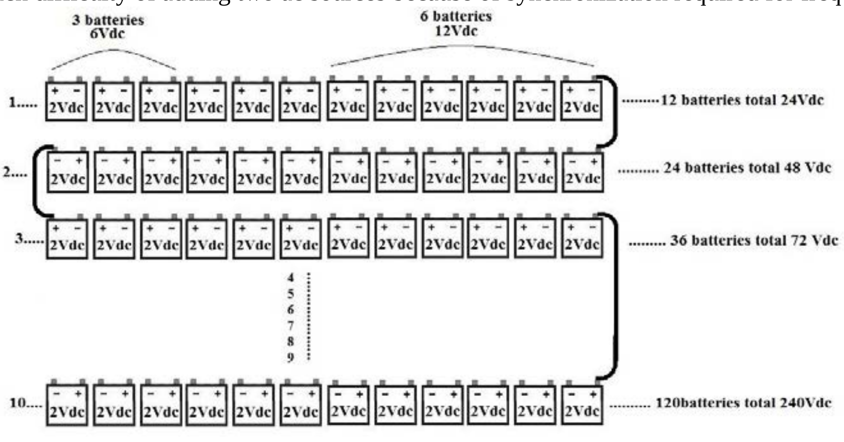


Fig. 1.Different Voltage levels for various dc Appliances.

Wiring plan can be laid for each electronic device at different desirable level of dc by simply connecting each unit cell of battery according to the required nominal level of voltage. Generalized dc supply may be formed by simple addition of unit cell of each 2Vdc battery which concludes 6Vdc supply for mobile charger, 12/24Vdc supply for LED lights, fans, internet routers. Connecting 12 batteries of each 2Vdc to form 24Vdc and 24 batteries of each 2Vdc to form 48Vdc supply for dc motors which couples submersible water pumps, washing machines, compressors for air condition and refrigeration systems. 120 batteries of each 2Vdc to form 240Vdc supply as shown in Fig. 1, using inverter for simple conversion to 240Vac universal power supply which is the most efficient way of conversion as whole system is transformer less.

## 3. Methodology

Steps for calculating size of Solar Panels, battery sizing and rating of charge controller.

1.1. Load Calculation

Calculation load in watts, here in this case, assuming total load is 1000 watts.

1.2. Battery sizing

For 240Vdc system, 120 batteries of each 2Vdc are connected in series

Current= $I = \frac{1000}{240}$ = 4.167 Amps (1)

Considering backup time is 14 hours, therefore we need 120 batteries of 2Vdc, 58.55Ah each. Drived a generalized formula in equation 2.

Battery Sizing $= \frac{14}{240}$ X Load (2)

1.3. Solar PV Sizing

Average charging at day time is 10 hours, for charging battery bank we need 5.833 Amps. Experimental results shows that 100 watt PV solar panel produce average current of 4 Amps, therefore from unity method we conclude that 25 watts solar panel can produce 1 Amps, hence required solar PV ratting is equal to 145.825 watts (5.833x 25). 240vdc battery system will be charged by total number of 20 solar panels of each 18-20Vdc all connected in series as shown in Fig. 2.

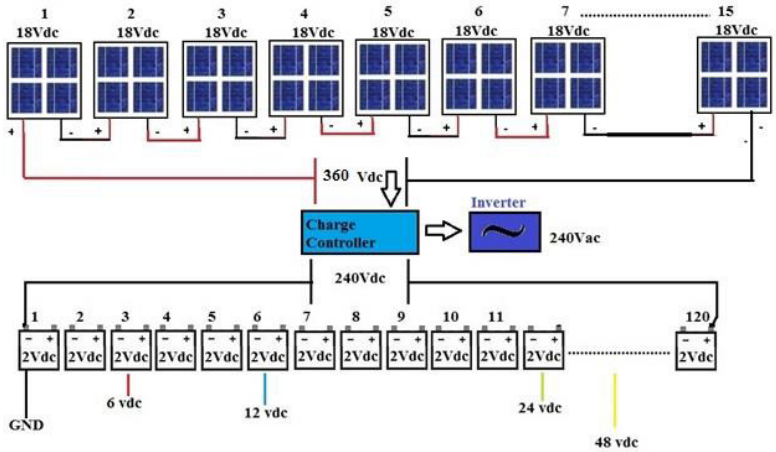


Fig. 2. Series combination for solar PV and Batteries

This dc power from PV array can be used for long transmission for even high roof buildings. Power remaies the same, hence increasing the voltage magnitude and minimizing the current reduces the power transmission losses. Finally generalized formula for solar PV sizing is as follow.

Solar Panel Sizing $= \frac{35}{240}$ x Load (3)

For 240Vdc system we connect 120 batteries of each 2 Vdc in series, similarly connecting 20 Solar panels of each 18Vdc in series to get 360 Vdc for PV Array, which is much better option for high rise buildings. From above calculations we conclude, for smooth running of load of 1000Watts, we need 20 numbers of PV solar panels each of 145 watts, getting total power of 2900 watts from PV array. System voltage becomes 360Vdc which

enhances the system efficiency and lowers the transmission losses. It can transmit PV array power up-to 120meters with no voltage drop. This system can be installed at high upraise buildings with maximum power outage.
Similarly for 12Vdc and 24Vdc storage systems generalized formularies are given below.

$$\text{Battery Sizing} = \frac{14}{12} \text{ x Load} \tag{4}$$

$$\text{Solar Panels Sizing=} = \frac{35}{12} \text{x Load} \tag{5}$$

$$\text{Battery Sizing} = \frac{14}{24} \text{ x Load} \tag{6}$$

$$\text{Solar Panels Sizing} = \frac{35}{24} \text{x Load} \tag{7}$$

More generalized form of equations are as below.

$$\text{Battery Sizing} = \frac{14}{V} \text{ x Load} \tag{8}$$

$$\text{Solar Panels Sizing} = \frac{35}{V} \text{x Load} \tag{9}$$

Where *V* denotes various level voltage system, ie:, 12Vdc, 24Vdc, 48Vdc or 240Vdc

## 4. Smart load shedding techniques

Solar power is greatly affected by solar radiations coming from sun, weather is changing abruptly due to excess emission of $CO_2$ in the atmosphere which dis-balance our weather system. PV output varies due to rapid weather change, it can be forecasted and on the basis of weather forecasting, load management could be done, to store more energy in batteries for rainy days, this extra energy comes from utility or it can also be done by switching off less priority devices during cloudy days. During cloudy days temperature falls down, taking benefit from this instead of running fans, dc inverter Air conditioners and dc Inverter refrigerators at full speed, lowering the speed will help us to save 35 % of energy and achieving the desired temperature in less time [5], which could be much helpful for saving battery storage.

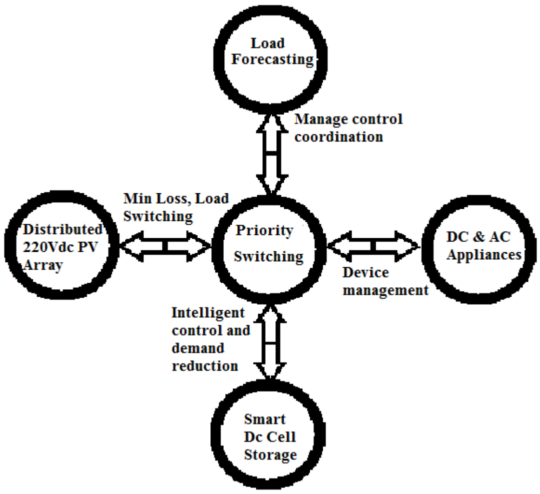


Fig.3. Priority switching

It can also be done to minimize the excessive load by turning it off using priority switching, simultaneously light intensity sensors allows to control window curtains to open intelligently, in order to utilize maximum sunlight in

room during day hours and fresh air from outside by controlling windows shutters directly getting feedback from temperature sensors. Integrating different wireless based circuit breakers at load side allows to switch load automatically on getting feedback from weather forecast and also controlling the priority devices in same manner [6]. Saving extra ampere hours in battery for cloudy days using smart 220Vdc PV array is shown in Fig. 3.
The example below shows consumption of 2916 W PV connected to L1 (Battery) and L2 (Load). During the day, the PV system connected to L2 provides the energy requirements to Load. The Solar Battery connected to L1 is free to store solar energy in the battery. The system tells the smart meter that the day’s consumption is covered and the meter balances the power and remains on 0 W. This leaves more solar energy available to charge the battery as shown in Fig. 4a.

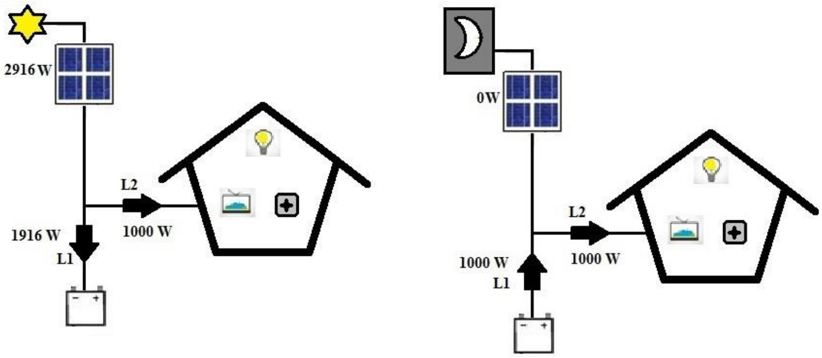


Fig. 4. (a) Day; (b) Night.

During the night as shown in Fig.4b. The battery adjusts the consumption of the load, in this way there is more solar energy available for self-consumption, especially on bad-weather days or between seasons [7].

## 5. Conclusions

This paper presented a smart load management scheme for domestic use fed by local distributed generation of solar PV array. 1KW of different loads were classified according to their priority, switching through wireless switches on feedback from weather forecast from atmosphere. Dc loads are directly fed though battery storage during unavailability of solar energy during cloudy hours or night time and simultaneously from PV array during sun shine, which enhance the overall efficiency of the system, storage is directly charged by Smart dc PV array during day time and efficiently used during night hours. The goal of this paper is to justify the efficient use dc appliances to minimize the losses during conversion from dc-ac-dc for solar PV array. Generallized equations for solar PV and battery sizing have been drived using experimental results. A technique was develop to prevent the total blackout in system and using the priority load without affecting the backup time of storage at night hours. It was demonstrated that the proposed smart scheme can be useful in efficiently managing the various dc and ac loads together with priority switching and proper sizing of storage and PV array lead to the cheaper solution for domestic loads.

## References

1. M. Wolsink, ”The research agenda on social acceptance of distributed generation in smart grids: Renewable as common pool resources”, Renewable and Sustainable Energy Reviews, vol. 16.1, January 2014
2. T Shibata, K Sakai and Y Okabe, “Design and implementation of an on-demand dc grid in Home”, IEEE, 2015
3. H. Dick, H. Eden, G. Fischer and J. Zietz, “Empowering users to become designers: Using Metadesign environments to enable and motivate sustainable energy decisions”, Colorado University, 2014
4. T. Sousa, et al, “Intelligent energy resource management considering vehicle-to-grid: a simulated approach”, IEEE - Smart Grid, vol. 3.1, pp. 535-542, March 2014
5. R. Kraus and M. Trivette, “Direct Current (dc) Power system for Application Requiring Best in Class Energy Efficiency and Total Cost of Ownership”, GE Validus Joint White Paper, 2013
6. K. Moslehi, “A reliability perspective of the smart grid”, Smart Grid, IEEE Transactions, vol. 1.1, pp. 57-64, June 2014
7. P. Savage, "Dc Micro-grid – Benefits and Barriers," Yale School of Forestry and Environmental Study, July 2013